# Developing Models for Enhanced Learning in Engineering

**Simon CAROLAN, Ecole Centrale de Nantes, simon.carolan@ec-nantes.fr**
**Morgan MAGNIN, Ecole Centrale de Nantes, morgan.magnin@ec-nantes.fr**
**Christine EVAIN, Ecole Centrale de Nantes, christine.evain@ec-nantes.fr**
**Guillaume MOREAU, Ecole Centrale de Nantes, guillaume.moreau@ec-nantes.fr**
**Francisco CHINESTA, Ecole Centrale de Nantes, francisco.chinesta@ec-nantes.fr**

Over the past fifty years, higher education has undergone major transformations, widening its scope with promises of education for the masses and effectively democratising the educational process. This has had an undeniable impact on human development as the education-for-all movement spreads worldwide. With these evolutions come a new set of challenges as these transformations are creating issues yet to be resolved. Educators are struggling to deal with increasingly sizeable classes yet many are reluctant to see pedagogical sciences enter into the sacred realm of the university.

Leading pedagogues are highlighting the importance of developing a pedagogical discourse within the context of this opening and democratisation process. This discourse should allow institutions to assimilate the massification, successfully handle the increasing heterogeneity of their students, prevent students from being failed by the system, guarantee the democratisation of the learning process and guarantee the mastering of quality skills and knowledge (Romainville, 2004).

Concurrently, augmented or enhanced learning has emerged as a way of improving learning processes by adapting the learning experience to the heterogeneous profiles of contemporary students (Goodman, 2001). Within this environment, technological advances are allowing these students to develop their knowledge and understanding through situation-based learning (Blumenfeld, 1991).

Working with the constraints identified by Romainville and Goodman in mind, we set about designing and building integral pedagogical tools that are adaptable to the field of engineering studies and studying their application to course material through the scenarisation of teaching sequences within the context of courses given at the Ecole Centrale de Nantes.

## Defining Structural Elements

In order to begin our reflections we examined the structure of a traditional university course that can be separated into sequences of lectures, seminars, practicals and autonomous work.[1] These elements can be qualified in other ways. For example, lectures can be considered as the transmission of notions or concepts, seminars can be considered as the drill and practice and the synthesis of this information, practicals can be considered as the deepening of knowledge through analysis and autonomous work as the application of these skills and knowledge to different contexts. Consistent lifelong learning will subsequently lead to learners becoming experts of the various domains. From this analysis, we identified and defined a possible four-tier structure for the lesson. These tiers are to be referred to as Notions, Synthesise, Deepen, Expert.

We have therefore elaborated a hierarchy that mimics this structure within an enriched ePub file.[2] This structure could equally be produced within a website but we have initially favoured the ePub format for our developments as it functions both online and offline on any device equipped with an adapted ePub reader. Within this file we will able to put a variety of content that can be fully indexed including video files, audio files, images, equations and interactive quizzes and exercises.

In addition, as a research team, we are keen to harness the full potential of these evolutions in order

[1] In order to establish a generic model, we initially considered a traditional university-level course. A variety of course structures exist and they will be the object of subsequent studies.

[2] ePub is an electronic publishing norm that contains HTML, CSS and Javascript codes. It allows for the creation of dynamic electronic documents.

to produce a learning environment that is adapted to the engineer in the 21st century. In order to achieve this, we have decided to integrate the ground-breaking work that is being undertaken in the institution's laboratories into the innovative teaching supports that are enabling the students to interact with the material both within the classroom and beyond (Laurillard, 2009). The development of enriched teaching supports is a part of a wider movement within the Ecole Centrale de Nantes that seeks to develop the role of ICT in Education. Within the scope of this communication, we will focus on two particular innovations that are proving to be promising avenues for exploration within our pedagogical project.

## eZoomBook

The first of these evolutions is the eZoomBook concept that recently emerged from cross-laboratory cooperation at the Ecole Centrale de Nantes. eZoomBook is a methodology and an associated platform for the structuring and the valorization of multi-scale documentation. eZoomBook is presented in the shape of an electronic book or document that is presented in multiple versions. These versions range from the complete version of a document to a series of abridged versions. The abridged versions contain either an alternation of original quotes and content summaries, or a superposition of quotes in a logical suit or simply content summaries. Each version of the document corresponds to a given reading time and level of difficulty. The reader is then effectively free to navigate between the different levels and can therefore personalize the content at their disposal in function of their interest and ability.

It is important when integrating such features into the learning process to envisage 'half-baked' solutions for the successful exploitation of the material or technology that will allow the teacher to complete the creative process (Kynigos, 2007 cf. Laurillard, 2009). In line with these recommendations, we have elaborated a few pedagogical scenarios for the use of this material.

The first of these scenarios is eZoomBook as an interactive coursebook. The multi-scale feature of such a document would allow the student to adapt the content in function of the context of his learning. The abridged level could be considered as the coursebook in revision mode, an intermediary level could be considered as the classroom mode and the complete version could be considered as the further reading mode.

In the same way, we could imagine eZoomBook as a tool for the structuring of flip teaching. In a flip classroom, during the initial phase of the lesson, the students are invited to discover the subject that is to be taught before the lesson takes place. This allows them to undertake research into the subject in order to gain understanding of the principal concepts. Then, during a second praesential phase undertaken with the teacher, the students works on the drill and practice of the concepts. This work can eventually be complemented through a period of project-based learning. In this case, eZoomBook takes on its full meaning. The student can examine a synthesised version of the concepts in preparation for class. Then, he goes to the heart of the subject in the presence of the teacher by discovering a higher reading level. Then he moves onto the full version of the document in order to complete an independent exercise.

These are just a few of the possibilities offered by the integration of eZoomBook in pedagogical documents. They allow students and teachers to have greater control over the content of their learning and enables the content of the course to be adapted to the levels of the heterogeneous learners whilst allowing them to understand, through contextualisation, where they stand in relation to the bigger picture. eZoomBook affords learners a certain degree of autonomy and a greater engagement with content.

## Numerical Simulators

These characteristics are common to the second of the present evolutions, the integration of

simulators within these multi-scale documents. These simulators allow students to reproduce complex scientific phenomena that are impossible to reproduce in the classroom environment, in a rapid, convenient and portable fashion.

The same could indeed be said for textbooks but whilst traditional paper books and electronic files allow the student to experience a concept in a defined context, simulators that are integrated into enriched documents allow students to interact with data for any given value and to see the results of this process directly. Students are able to interact with the data, allowing them to see the resulting scenarios that arise when they modify the different variables for many given data sets. This enhances both the students understanding and motivation.

We are currently experimenting with the integration of numerical simulators into ePub files. Among these numerical simulators, many have been developed using the innovative Proper Generalized Decomposition or PGD methodology that was recently proposed by members of the Civil and Mechanical Engineering laboratory (GeM) at the Ecole Centrale de Nantes.

The novel technique provides practical means for obtaining meta-models for complex scenarios. These meta-models are then solved at real-time feedback rates. PGD techniques can help in developing suitable strategies for solving complex, state-of-the-art engineering and physics problems at real time rates. These simulations are being used to solve multidimensional problems in varied contexts and can be applied to almost any field of the engineering cursus. In addition, incorporated into portable documents and devices, these simulations can interact with user inputs seamlessly.

The integration of these simulators in pedagogical documents serves a double purpose. As well as providing the students with computing facilities, they provide tangible links between the teaching and the research activities of the institution as students are confronted with the resolution of real-life situations through the application of the theorem and the tools that are developed in the laboratories and presented to them in class.

## Enhancing Content

These interactive supports are being integrated into existing ePub technology ensuring that can be consulted both online and offline and are readable on desktop computers in addition to the majority of tablets and smartphones. This was considered to be essential when undertaking this work as we are moving towards the democratization of higher education but the democratisation of digital technology appears to be evolving at a slower pace (Palfrey & Gasser, 2008). In light of this, developments must be compatible with a wide variety of devices. Whilst inequalities of this kind may subsist, almost all students on modern campuses have access to digital technology in one form or another.

The access to information and media may be improving but the jury is still out on the question of the enrichment of educational content through media. As highlighted in Implementing Technology-Enhanced Learning (Laurillard, 2009), these enrichments can sometimes be considered to be disruptive to the learning process. However, when they are integrated correctly in a lesson in a process involving all of the actors of the educational process with the teacher as the 'conductor', dynamic, interactive and gamified content can be beneficial both in terms of student motivation and understanding.

In order to ensure that institutions cater for the growing needs of the upcoming digitally connected generations and their digitally aware teachers, they are investing heavily in pedagogical engineers and ICT in Education units that in line with the recommendations of the European SEEDS Framework are proving essential in the development of 'intelligent' pedagogical content in all the meanings of the word (Laurillard, 2009).

## Experimental Environments

Having examined the foreseeable implications of undertaking an enhanced learning venture and the opportunities that it could offer, we set about producing our first complete sequence. For this process, we focussed on the sequence devoted to Sorting Algorithms in the Semester 6 Elective Course *Algorithmic and Programming* at the Ecole Centrale de Nantes. This course was identified as representative of the structure that was defined in the initial phase of experimentation. It was also selected for the visual nature of the course's subject matter that has originated many collaborative media developments that therefore provides a wide palette of available content. It is also striking for the importance it accords to student interactivity during the practical sessions. Using such a course as a framework provided us with the opportunity to research, examine and demonstrate a great deal of the various enrichments that were identified in the initial research phase.

The development phase was undertaken by researchers and research engineers on the basis of the meetings that took place between the teacher and the development team. As described earlier, this resulted in the creation of a technically sound 'half-baked' coursebook that will allow the teacher to assimilate and personalise the content further adapting it to the context of his class.[3]

## Perspectives

This project holds many bright perspectives. Following an initial phase of informal study, we have engaged in a process of scientific experimentation that will enable us to analyse the impact of these developments on both the motivation of students and their reception, understanding and assimilation of knowledge and skills.

Following on from the results of these initial experiments, we will be able to expand the procedure to incorporate sequences from a range of subjects. We are equally interested in the extrapolation of these models to other domains of study. In order to facilitate these processes and to encourage the growing momentum around these tools, the development team have produced a series of generic structured models that will allow teachers to insert their content easily for a professional result.

As we encounter these different subjects and subject areas, we will see our models evolve to adapt to the specificities of different courses and teaching environments. Whilst these learning supports can in many ways be considered as revolutionary, we prefer to consider them as evolutions within the learning environment that reflect the legacy of more traditional pedagogical models. To ensure this continuity, the supports are being developed within the different teaching departments of the institution involving close collaboration with the different pedagogical teams. In addition, the development team is considering the anthropological, psychological and sociological impact of these novel forms of human-machine interaction, ensuring the long-term viability of this venture.

## References

Blumenfeld, P. C., et al. Motivating Project-Based Learning: Sustaining the Doing, Supporting the Learning. *Educational Psychologist*, vol. 26, issue 3-4, Routledge. New York : 1991.

Laurillard, D. et al. Implementing Technology-Enhanced Learning. *Technology-Enhanced Learning*, 2009, Part 5, 289-306, Springer. Houten : 2009.

Goodman, P. S., (Ed.). *Technology Enhanced Learning: Opportunities for Change*, Taylor & Francis, Routledge. New York : 2001.

Palfrey, J., & Gasser, U., (2008). *Born Digital : Understanding the first generation of digital natives*. New York : Basic Books.

[3] To find out more about these developments, we invite readers to visit http://simontice.wordpress.com/

Romainville, M., (2004). Esquisse d'une didactique universitaire. *Revue francophone de gestion* : Special issue dedicated to the Deuxième prix de l'innovation pédagogique en sciences de gestion pp. 5-24. Paris : CIDEGEF